1. A method of selectively separating a target small molecule from an aqueous solution comprising:

contacting the aqueous solution with a water-soluble polymer that is capable of forming a water-soluble polymer/small-molecule complex with the target small molecule for a time sufficient to allow the target small molecule to form the complex with the water-soluble polymer; and

treating the aqueous solution by ultrafiltration with an ultrafiltration membrane, the ultrafiltration membrane being selected to separate the target small molecule from the solution by having the water and the other dissolved chemicals pass through the membrane while the water-soluble polymer/molecule complex and water-soluble polymer is retained and concentrated into an aqueous solution containing water-soluble polymer/molecule complex and water-soluble polymer.

2. The method of claim 1, wherein the water-soluble polymer is initially dissolved in a reaction solution, the contacting comprising mixing the aqueous solution with the reaction solution.

3. The method of claim 1, further comprising releasing the target small molecule from the aqueous solution containing water-soluble polymer/molecule complex.

4. The method of claim 3, wherein the target small molecule is selected from the group consisting of sulfuric acid, phosphoric acid, boric acid, arsenic acid, perchloric acid, arsenous acid, silicic acid, selenic acid, selenious acid, antimonous acid, iodine, ammonia, organic acids including acrylic acid, N-methyliminodiacetic acid, DTPA, nitrilotriacetic acid, inimododiacetic acid, and ethylenediaminetetraacetic acid, organic amine bases including methylamine and dimethylamine in general, and aromatic amines and polyamines, organic neutral molecules including alcohols, aldehydes, nitriles, amides, maleimide, maleonitrile, fumaronitrile, and acrylamide, food additives, drugs, pesticides, polypeptides, antibodies, pharmaceutical compounds, antibiotics, coenzymes, and nucleic acids.

5. The method of claim 3 wherein the target small molecule is released by adding a stripping solution to the aqueous solution containing water-soluble polymer/molecule complex.

6. The method of claim 5 wherein the stripping solution comprises one or more of the following: deionized water, basic solution, acidic solution, organic solvents, hot water, cold water, and competing ligands.

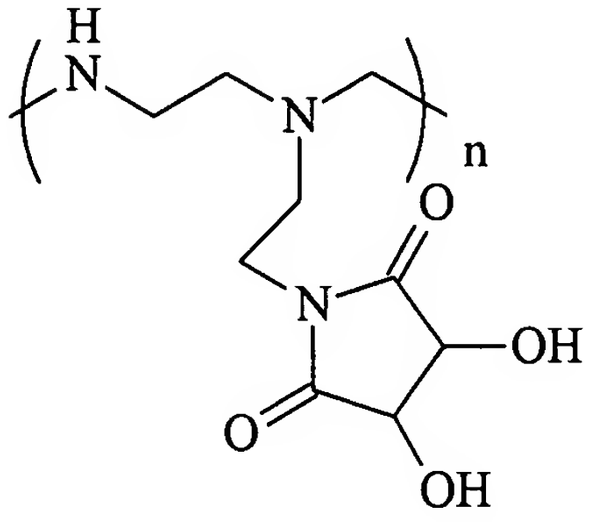
7. The method of claim 3 wherein the target small molecule is released by electrodialysis.

8. The method of claim 1, wherein the target small molecule is selected from the group consisting of sulfuric acid, phosphoric acid, boric acid, arsenic acid, perchloric acid, arsenous acid, silicic acid, selenic acid, selenious acid, antimonous acid, iodine, ammonia. organic acids including acrylic acid, N-methyliminodiacetic acid, DTPA, nitrilotriacetic acid, inimododiacetic acid, and ehylenediaminetetraacetic acid, organic amine bases including methylamine dimethylamine, alkylamines in general, and aromatic amines and polyamines, organic neutral molecules including alcohols, aldehydes, nitriles, amides, maleimide, maleonitrile, fumaronitrile, and acrylamide, food additives, drugs, herbicides pesticides, polypeptides, antibodies, pharmaceutical compounds, antibiotics, coenzymes, and nucleic acids.

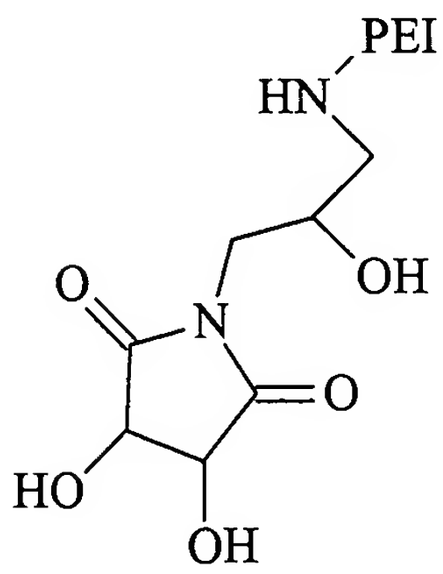
9. The method of claim 1, wherein the water-soluble polymer contains one or more binding groups selected to bind the target small molecule.

10. The method of claim 9, wherein the one or more binding groups are selected from the group consisting of diol derivatives, triol derivatives, tetraol derivatives, glucuron derivatives, thiol derivatives, dithiol derivatives, amide derivatives, polyphosphonic acid derivatives, guanidinum derivatives, carboxylate derviatives, permethylate derivatives, cavity-containing host groups, molecules containing a boron atom capable of functioning as a Lewis acid center, and affinity groups.

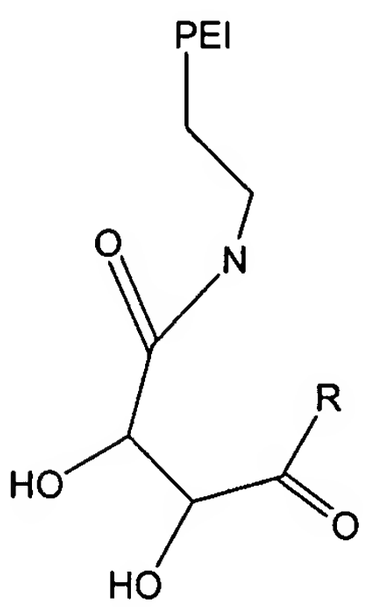
11. The method of claim 10, wherein the water-soluble polymer has a formula selected from the group consisting of



wherein n is an integer between about 12 and about 12,000;

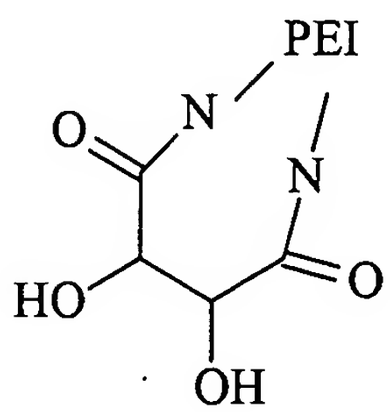


wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;



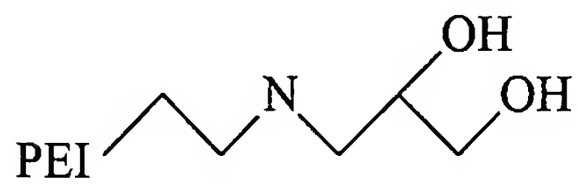
R = OH, OEt

wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;

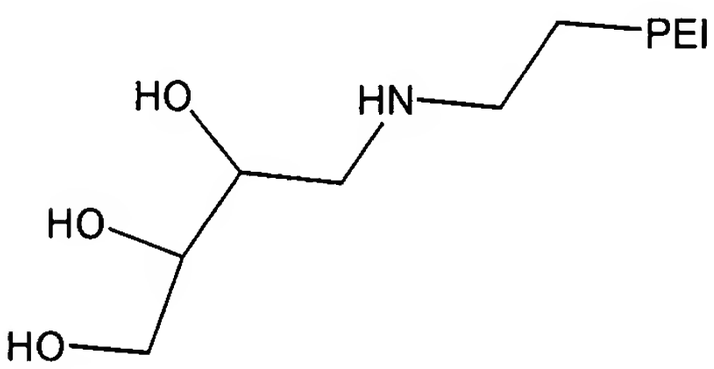


wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;

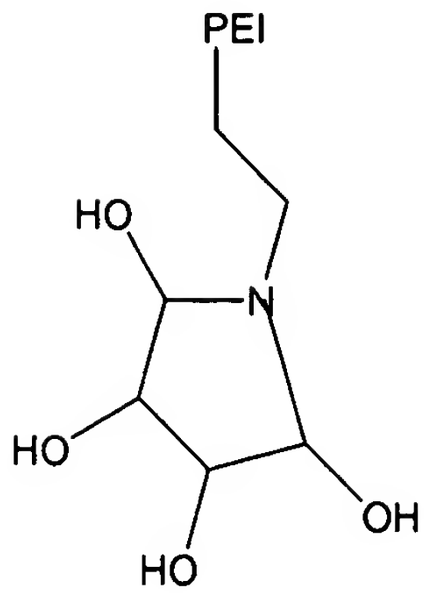
and



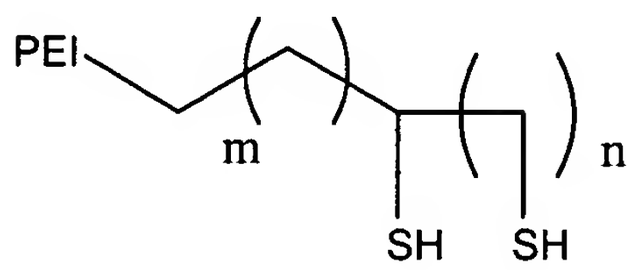
wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;



wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;



wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;



n = 0, 1, 2, 3

m = 0. 1, 2, 3

wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;

12. The method of claim 1, wherein the water-soluble polymer comprises a water-soluble backbone polymer with attached small molecule binding groups.

13. The method of claim 12, wherein the backbone polymer is selected from the group consisting of polyvinylamine, polyallylamine, polyacrylamide, polyethylenimine, polyacrylic acid, polymethacrylic acid, polyvinylalcohol, polyvinylacetate, polypyrrol, and hyperbranched polymers.

14. The method of claim 12, wherein the binding groups are selected from the group consisting of a tartrate deriviative, a diol, a triol, a tetraol, a thiol, a dithiol, a cavity-containing

host groups, cage-shaped host, a calixarene-containing polymer, a cyclodetran containing polymer, molecules containing a boron atom capable of functioning as a Lewis acid center, an antibody, a Fab fragment of an antibody, a $F(ab)_2$ of an antibody an antigen, and a polypeptide.

15. The method of claim 14, wherein the backbone polymer is polyethylenimine.

16. The method of claim 1, wherein the water-soluble polymer is selected from the group consisting of polyethylenimine, permethylated polyethylenimine, guanidinium polyethylenimine, carboxylated polyethylenimine, phosphoralated polyethylenimine, poly(ethylenimine ethyenesulfide), glycidol polyethylenimine, tartrated polyethylenimine, diphosphoralated polyethylenimine, polyvinylamine, polyacrylic acid, polyvinylalcohol, polyvinylacetate, polypyrrol, polymethacrylic acid, and hyperbranched polymers.

17. The method of claim 16, wherein the water-soluble polymer has a molecular weight in the range from about 5,000 to about 100,000.

18. The method of claim 17, further comprising releasing the target small molecule from the aqueous solution containing water-soluble polymer/molecule complex.

19. The method of claim 17, further comprising releasing the target small molecule from the aqueous solution containing water-soluble polymer/molecule complex.

20. A method of selectively separating a target small molecule from an aqueous solution comprising:

contacting the aqueous solution with a water-soluble polymer that is capable of forming a water-soluble polymer/molecule complex with the target small molecule for a time sufficient to allow the target small molecule to form the complex with the water-soluble polymer, the water-soluble polymer having been pre-purified so as to have polymer molecule sizes capable of being retained by an ultrafiltration membrane with a molecular weight cutoff value of a first pre-selected level and essentially free of polymer molecule sizes capable of passing through a membrane with a molecular weight cutoff value of a second pre-selected level, the first pre-selected level being larger than the second pre-selected level; and

treating the aqueous solution by ultrafiltration with an ultrafiltration membrane, the ultrafiltration membrane being selected to separate the target small molecule from the solution by having the water and the other dissolved chemicals pass through the membrane while the water-soluble polymer/molecule complex is retained and concentrated into an aqueous solution containing water-soluble polymer/molecule complex.

21. The method of claim 20, wherein the water-soluble polymer is initially dissolved in a reaction solution, the contacting comprising mixing the aqueous solution with the reaction solution.

22. The method of claim 20, further comprising releasing the target small molecule from the aqueous solution containing water-soluble polymer/molecule complex.

23. The method of claim 22, wherein the target small molecule is selected from the group consisting of sulfuric acid, phosphoric acid, boric acid, arsenic acid, perchloric acid, arsenous acid, silicic acid, selenic acid, selenious acid, antimonous acid, iodine, ammonia, organic acids including acrylic acid, N-methyliminodiacetic acid, DTPA, nitrilotriacetic acid, inimododiacetic acid, and ethylenediaminetetraacetic acid, organic amine bases including methylamine and dimethylamine, organic neutral molecules including alcohols, aldehydes, nitriles, amides, maleimide, maleonitrile, fumaronitrile, and acrylamide, food additives, drugs, pesticides, polypeptides, antibodies, pharmaceutical compounds, antibiotics, coenzymes, and nucleic acids.

24. The method of claim 22 wherein the target small molecule is released by adding a stripping solution to the aqueous solution containing water-soluble polymer/molecule complex.

25. The method of claim 24 wherein the stripping solution comprises one or more of the following: deionized water, basic solution, acidic solution, organic solvents, hot water, cold water, and competing ligands.

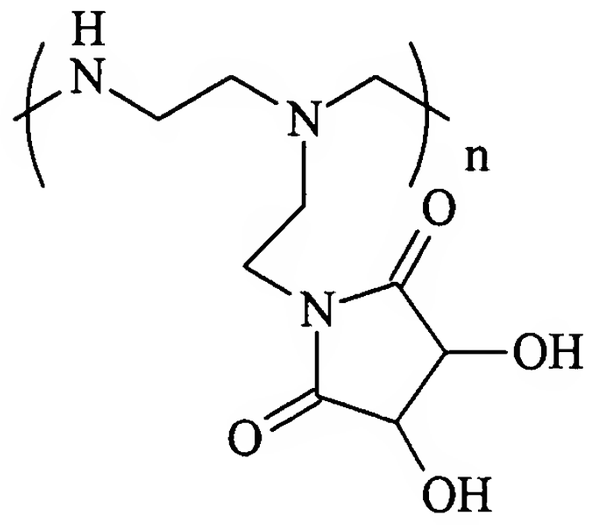
26. The method of claim 22 wherein the target small molecule is released by electrodialysis.

27. The method of claim 20, wherein the target small molecule is selected from the group consisting of sulfuric acid, phosphoric acid, boric acid, arsenic acid, perchloric acid, arsenous acid, silicic acid, selenic acid, selenious acid, antimonous acid, iodine, ammonia organic acids including acrylic acid, N-methyliminodiacetic acid, DTPA, nitrilotriacetic acid, inimododiacetic acid, and ethylenediaminetetraacetic acid, organic amine bases including methylamine dimethylamine, alkylamines in general, and aromatic amines and polyamines, organic neutral molecules including alcohols, aldehydes, nitriles, amides, maleimide, maleonitrile, fumaronitrile, and acrylamide, food additives, drugs, herbicides pesticides, polypeptides, antibodies, pharmaceutical compounds, antibiotics, coenzymes, and nucleic acids.

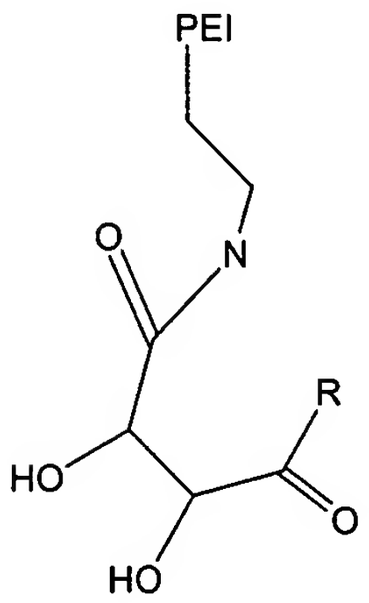
28. The method of claim 20, wherein the water-soluble polymer contains one or more binding groups selected to bind the target small molecule.

29. The method of claim 28, wherein the one or more binding groups are selected from the group consisting of diol derivatives, triol derivatives, tetraol derivatives, thiol derivatives, dithiol derivatives, amide derivatives, polyphosphonic acid derivatives, guanidinum derivatives, carboxylate derviatives, permethylate amine derivatives, cavity-containing host groups, a cage-shaped host, a calixarene-containing polymer, a cyclodetran-containing polymer, molecules containing a boron atom capable of functioning as a Lewis acid center, and affinity groups.

30. The method of claim 29, wherein the water-soluble polymer has a formula selected from the group consisting of

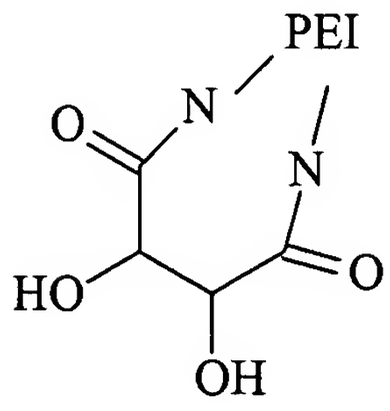


wherein n is an integer between about 12 and about 12,000;

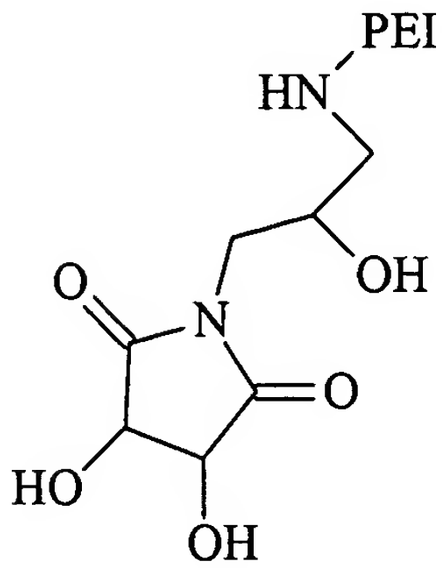


R = OH, OEt

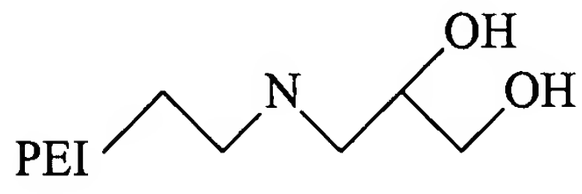
wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;



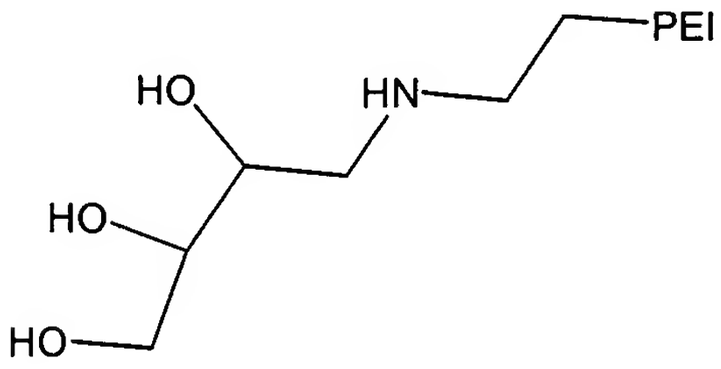
wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;



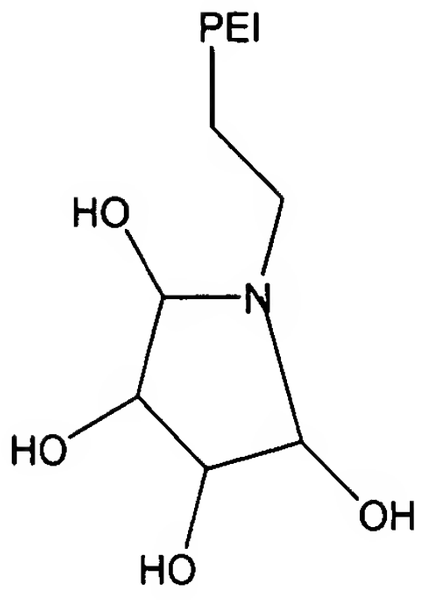
wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000; and



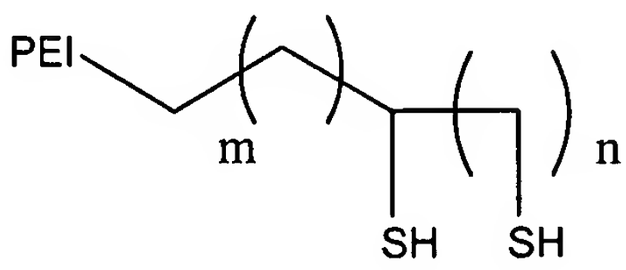
wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000



wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;



wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;



n = 0, 1, 2, 3

m = 0. 1, 2, 3

wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;

31. The method of claim 20, wherein the water-soluble polymer comprises a water-soluble backbone polymer with attached small molecule binding groups.

32. The method of claim 31, wherein the backbone polymer is selected from the group consisting of polyvinylamine, polyallylamine, polyacrylamide, polyethylenimine, polyacrylic acid, polymethacrylic acid, polyvinylalcohol, polyvinylacetate, polypyrrol, and hyperbranched polymers.

33. The method of claim 31, wherein the binding groups are selected from the group consisting of a tartrate deriviative, a diol, a triol, a tetraol, a thiol, a dithiol, a cage-shaped host,

cavity-containing host groups, a calixarene-containing polymer, a cyclodextran-containing polymer, an antibody, a Fab fragment of an antibody, a $F(ab)_2$ of an antibody an antigen, molecules containing a boron atom capable of functioning as a Lewis acid center, and a polypeptide.

34. The method of claim 33, wherein the backbone polymer is polyethylenimine.

35. The method of claim 20, wherein the water-soluble polymer is selected from the group consisting of polyethylenimine, permethylated polyethylenimine, guanidinium polyethylenimine, carboxylated polyethyleneimine, phosphoralated polyethylenimine, poly(ethylenimine ethyenesulfide), glycidol polyethylenimine, tartrated polyethylenimine, diphosphoralated polyethylenimine, polyvinylamine, polyacrylic acid, polyvinylalcohol, polyvinylacetate, polypyrrol polymethylacrylic acid, and hyperbranched polymers.

36. The method of claim 35, wherein the water-soluble polymer has a molecular weight in the range from about 5,000 to about 100,000.

37. The method of claim 36, further comprising releasing the target small molecule from the aqueous solution containing water-soluble polymer/molecule complex.

38. A method of selectively separating a target small molecule from an aqueous solution comprising:

contacting the aqueous solution with a water-soluble polymer that is capable of forming a water-soluble polymer/molecule complex with the target small molecule for a time sufficient to allow the target small molecule to form the complex with the water-soluble polymer, the target small molecule being selected from the group consisting of boric acid, arsenic acid, arsenous acid, selenous acid, selenic acid, antimonous acid, the water- soluble polymer having been pre-purified so as to have polymer molecule sizes capable of being retained by an ultrafiltration membrane with a molecular weight cutoff value of a first pre-selected level and essentially free of polymer molecule sizes capable of passing through a membrane with a molecular weight cutoff value of a second pre-selected level, the first pre-selected level being larger than the second pre-selected level; and

treating the aqueous solution by ultrafiltration with an ultrafiltration membrane, the ultrafiltration membrane being selected to separate the target small molecule from the solution by having the water and the other dissolved chemicals pass through the membrane while the water-soluble polymer/molecule complex is retained and concentrated into an aqueous solution containing water-soluble polymer/molecule complex.

39. The method of claim 38, wherein the water-soluble polymer is initially dissolved in a reaction solution, the contacting comprising mixing the aqueous solution with the reaction solution.

40. The method of claim 38, further comprising releasing the target small molecule from the aqueous solution containing water-soluble polymer/molecule complex.

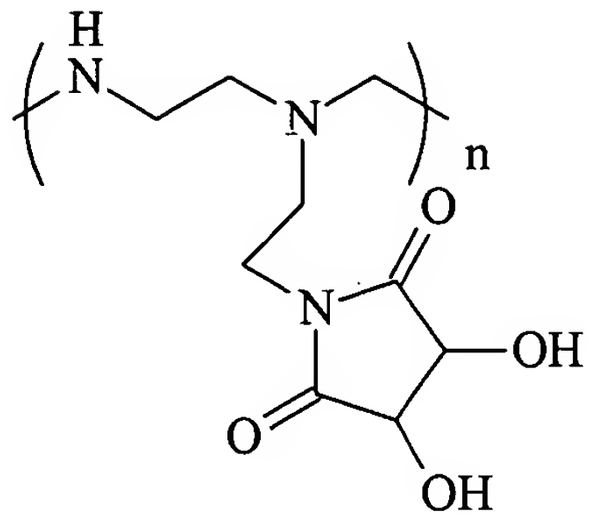
41. The method of claim 40 wherein the target small molecule is released by adding a stripping solution to the aqueous solution containing water-soluble polymer/molecule complex.

42. The method of claim 41 wherein the stripping solution comprises one or more of the following: deionized water, basic solution, acidic solution, organic solvents, hot water, cold water, and competing ligands.

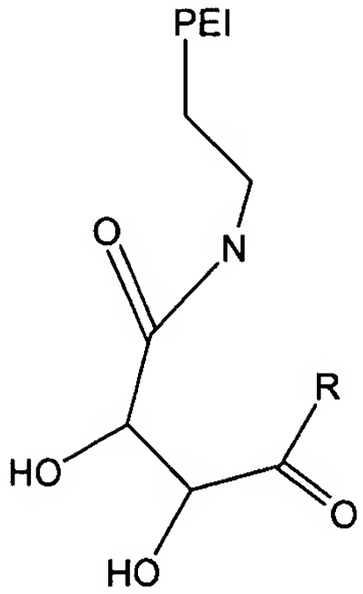
43. The method of claim 40 wherein the target small molecule is released by electrodialysis.

44. The method of claim 38, wherein the water-soluble polymer contains one or more binding groups selected to bind the target small molecule, the binding groups being selected from the group consisting of a tartrate derivative and a diol derivative.

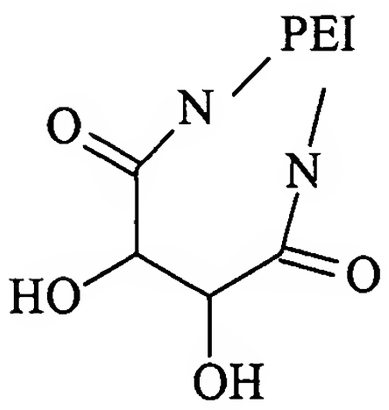
45. The method of claim 38, wherein the water-soluble polymer has a formula selected from the group consisting of



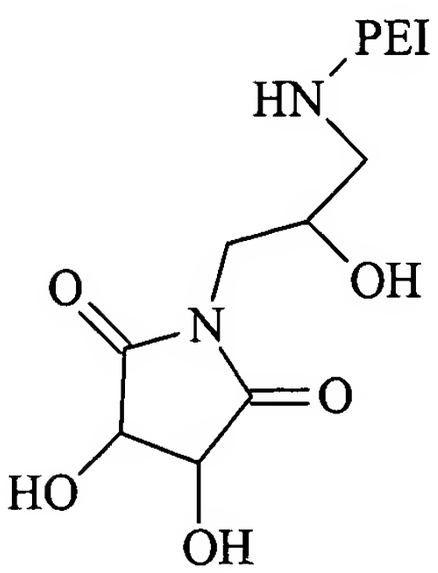
wherein n is an integer between about 12 and about 12,000;



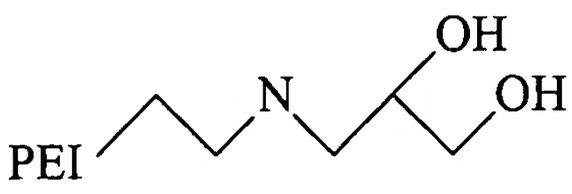
wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;



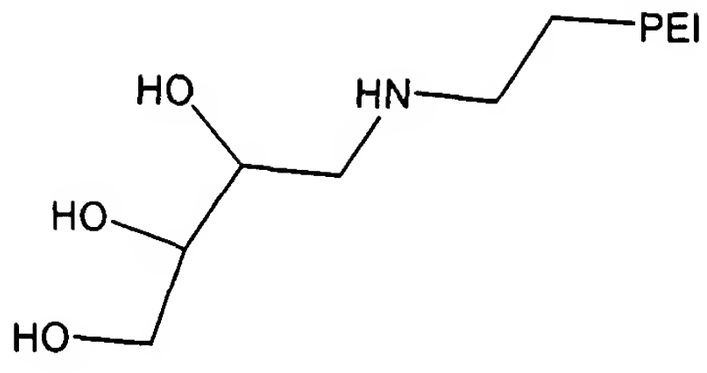
wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;



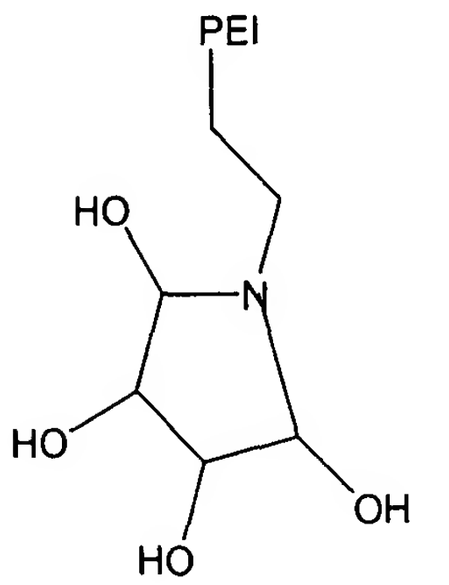
wherein PEI represents polyethylenimine have a molecular weight in the range from about 5,000 to about 100,000; and



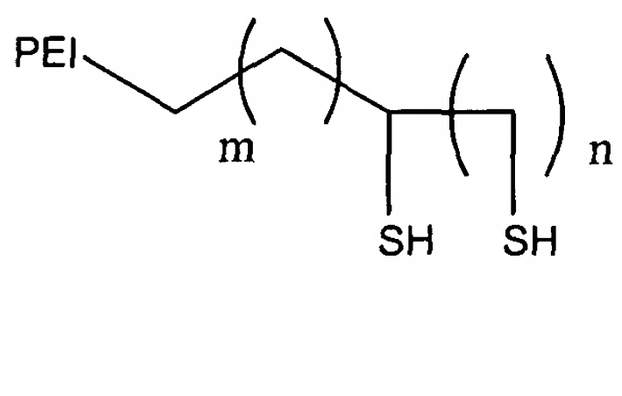
wherein PEI represents polyethylenimine with a molecular weight in the range from about 5,000 to about 100,000



wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;



wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;



wherein PEI represents polyethylenimine having a molecular weight in the range from about 5,000 to about 100,000;

46. The method of claim 45, wherein the water-soluble polymer has a molecular weight in the range from about 5,000 to about 100,000.

47. The method of claim 38, wherein the water-soluble polymer is polyethylenimine, permethylated polyethylenimine, guanidinium polyethylenime, phosphoralated polyethyleneimine, poly(ethylenimine ethyenesulfide), glycidol polyethylenimine, tartrated polyethylenime, diphosphoralated polyethylenime, polyvinylamine, or polyallylamine.

48. A method of selectively separating chromic acid and perchloric acid from an aqueous solution comprising:

contacting the aqueous solution with a water-soluble polymer that is capable of forming a water-soluble polymer/molecule complex with the chromic acid for a time sufficient to allow the target small molecule to form the complex with the water-soluble polymer; and

treating the aqueous solution by ultrafiltration with an ultrafiltration membrane, the ultrafiltration membrane being selected to separate the chromic acid from the solution by having the water and the other dissolved chemicals pass through the membrane while the water-soluble polymer/molecule complex is retained and concentrated into an aqueous solution containing water-soluble polymer/molecule complex.

49. The method of claim 48, wherein the water-soluble polymer is initially dissolved in a reaction solution, the contacting comprising mixing the aqueous solution with the reaction solution.

50. The method of claim 48, further comprising releasing the chromic acid or perchloric acid from the aqueous solution containing water-soluble polymer/molecule complex via eletrolydialysis.

51. The method of claim 48, wherein the water-soluble polymer comprises permethylated polyethylenimine.